ANIMAL PERFORMANCE AND FORAGE QUALITY IN LIMPOGRASS-NITROGEN AND LIMPOGRASS-AESCHYNOMENE PASTURES

BY

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To Harold and Deanna Husland,

thanks.

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ANIMAL PERFORMANCE AND FORAGE QUALITY IN LIMPOGRASS-NITROGEN AND LIMPOGRASS-AESCHYNOMENE PASTURES

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'Floralta' limpograss (*Hemarthria altissima* [Poir.] Stapf et C. E. Hubb.) has been under evaluation since 1974. This perennial grass is very productive and has a relatively high in vitro organic matter digestibility (IVOMD) compared to other tropical grasses. However, some studies have suggested that low N concentrations in Floralta limpograss may limit animal performance. The objective of this study was to compare average daily gain (ADG), carrying capacity (CC), and gain ha^{-1} of yearling steers grazing limpograss pastures that were 1) overseeded with the legume aeschynomene (*Aeschynomene americana* L.; LA) or 2) fertilized with N (LN).

Seasonal ADG was higher for LA than for LN pastures in 1985 ($P<0.01$, 0.55 vs. 0.27 kg) and 1986 ($P<0.05$,

0.85 vs. 0.54 kg). Thus, overseeding aeschynomene in limpograss pastures improved the quality of the diet consumed. Handplucked herbage of aeschynomene had mean crude protein (CP) and IVDOM concentrations of 25 decagram (dag) kg^{-1} DM and 75 dag kg^{-1} DM in 1995, and 25 dag kg^{-1} DM and 72 dag kg^{-1} DM in 1996, respectively. Handplucked limpograss had CP concentrations that were consistently above 7 dag kg^{-1} DM. Poor animal performance on LN pastures during the late summer and early fall could not, therefore, be directly related to protein deficiency.

Mean CC over the 126-day grazing season did not differ between systems. From early July to the middle of September, LN pastures had higher CC (9.4 vs 4.4 animals ha^{-1} in 1995, and 7.0 vs 5.5 animals ha^{-1} in 1996). These trends toward higher CC in LN pastures suggest that limpograss pastures fertilized with N (in the range used in this study) will generally produce more dry matter than limpograss pastures that are overseeded with legumes (not fertilized with N).

Seasonal gain ha^{-1} was higher in 1995 ($P<0.01$, 296 vs. 157 kg) for LA than for LN pastures and tended to be higher in 1996 (492 vs. 360 kg). There was a period x treatment interaction ($P<0.01$) in 1995, and pastures mixture produced higher gains ha^{-1} only from the middle

of August to early October. In 1986 there was no period x treatment interaction. These data indicate that productivity per unit land area can be increased by associating aeschynomene with limpograss, primarily due to increased diet quality.

CHAPTER I
INTRODUCTION

The need for efficient animal production is the basis for constantly trying to improve pasture production and forage quality, especially in the tropics and subtropics. As a part of this effort, grass-legume pastures have become a popular research topic, since the contribution of high quality forage to animal's diets is realized without the addition of large amounts of nitrogen (N) fertilizer. Also, legumes contribute symbiotically fixed N to the pasture system, thus increasing the efficiency of animal production.

'Floralta' limpograss (Hemarthria altissima [Poir.] Stapf and C. E. Hubb.) has been under evaluation in Florida since 1974 and has shown promise because of its high dry matter production and relatively high in vitro organic matter digestibility (IVOMD; Quesenberry et al., 1984). However, animals grazing limpograss (N fertilized) pastures produced low average daily gain, and it was previously suggested (Euclides, 1985; Sollenberger and Quesenberry, 1985; and Gleger, 1986) that low crude protein (CP) concentration (less than 5 percent) of Floralta might be responsible.

To improve animal performance on limpograss pastures different measures can be evaluated. These include overseeding of legume into limpograss sods and supplementation of animals grazing this forage with concentrates. In this experiment the overseeding of legume was used.

Aeschynomene (Aeschynomene americana L.), a summer annual that grows in Florida, is widely adapted (Hodges et al., 1982) and has high forage quality (Gildersleeve, 1982; Sollenberger et al., 1987b). Gomes (1978) speculated that this forage has potential for use in association with limpograss. Sollenberger et al. (1987b) suggested that the use of aeschynomene may improve animal performance on summer pastures during the "summer slump" period. A grazing study was conducted in 1985 and 1986 to determine whether this hypothesis is true.

CHAPTER II
LITERATURE REVIEW

General

Aeschynomene

The most widely adapted and commonly used tropical forage legume on peninsular Florida flatwoods soils (Spodosols) is aeschynomene (*Aeschynomene americana* L.; Pitman and Kretschmer, 1984). Aeschynomene, also known as jointvetch or deervetch, is a warm-season legume that has been used as a forage crop in central and southern Florida and has been observed growing in ditches and abandoned fields throughout the state (Chambliss, 1982). Moore and Hilman (1969) reported that aeschynomene is well adapted to Florida's wet prairies, which are subject to summer flooding.

Limpograss

'Floralta' limpograss (*Hemarthria altissima* [Poir.] Stapf and C. E. Hubb.) is the direct release of an increase of USDA plant introduction 364888 (Quesenberry et al., 1984). This introduction was first extensively evaluated in Florida in 1974. Limpograss is the common name for the species, because the introduction originated near the Limpopo river, which divides

Zimbabwe and Transvaal, South Africa (Wilms et al., 1970).

Characteristics

Aeschynomene

Aeschynomene is an upright, summer-annual legume which grows vigorously on fertilized and limed flatwoods and moist upland soils throughout Florida (Hodges et al., 1982). This legume is of the tribe *Aeschynomene* of the *Papilionoidae* subfamily of *Leguminosae* (Allen and Allen, 1981). Aeschynomene grows to 0.9 to 1.8 m in height, being taller in a thick stand than in a sparse one (Hodges and McCaleb, 1972). Leaves are medium green and approximately 20 by 75 mm in size. The leaf is divided into 25 to 60 leaflets, giving the plant a light and feathery appearance. The leaves are sensitive, folding together when touched or shaken (Hodges and McCaleb, 1972). Hodges et al. (1982) reported that the leaves and young stems of this legume are palatable to grazing animals.

Important attributes of aeschynomene are tolerance of wet soils and water logging, good regeneration from seed, good persistence, and excellent spread under heavy grazing (Bishop et al., 1985). Kretschmer and Bullock (1980) noted, however, that when initial flowering dates, growth habits, insect and disease damage, and short-term persistence were considered, the Florida commercial type was inferior to many other Aeschynomene accessions.

Miller and Williams (1981) found that aeschynomene was one of four legumes, in a study of 41 legume accessions, that survived and grew vigorously during a 6-month period of waterlogging. Nitrogenase activity was not reduced significantly in pot-grown aeschynomene plants subjected to flooding in the greenhouse (Albrecht et al., 1981). These authors also found that after 20 days of withholding water from the soil, nitrogenase activity of drought-stressed plants was much lower than that of either well-watered or flooded plants. Further, leaf water potentials were similar in flooded and well-watered plants.

Kretschmer and Bullock (1980) indicated in a review of literature that the most successful use of an Aeschynomene species has been in Florida where Aeschynomene americana L. has been used as a grazing forage in mixtures with permanent pasture grasses. Hodges et al. (1982) reported that aeschynomene has the capability of furnishing high quality grazing from 1 August to 1 November, a crucial period when perennial grass quality does not meet the needs of nursing cows or grazing calves in Florida. Hodges et al. (1974) also pointed out that aeschynomene improved the quality of a summer digitgrass pasture, but it left a winter and spring gap in the forage supply.

Limpograss

Floralta limpograss is a stoloniferous perennial tropical grass of the tribe *Andropogonea* of the family *Poaceae* (Quesenberry et al., 1984). Floralta produces few seed and must be propagated vegetatively. Quesenberry et al. (1984) noted that Floralta has an intense purple coloration under cool temperature stress or fertility deficiency. Also, Floralta appears to be similar to other released cultivars of limpograss in winter hardiness. Oakes (1980) reported survival rates of 80, 84, 78, and 76% for Floralta, Redalta, Greenalta, and Bigalta, respectively.

Schank (1972) found that the basic chromosome number of *Hemarthria altissima* is X=9. Nine of eleven *Hemarthria* introductions were diploid (2N=18), and two were tetraploid (4N=36). Floralta is a tetraploid (Quesenberry et al., 1982). The tetraploid clones of *Hemarthria altissima* generally have larger stems and higher in vitro organic matter digestibility (IVOMD) than the diploid clones (Schank et al., 1973; Ruelke, 1978; Quesenberry et al., 1982).

Schank et al. (1973) indicated that genetic improvement of *Hemarthria altissima* lines was considered feasible because of their ability to persist under flooding, drought, and freezing temperatures. They found that IVOMD was significantly higher in a coarse-stemmed tetraploid line than in any diploid lines studied. This was also reported by Ruelke (1976) and Quesenberry et al. (1982). Further studies of stem morphology revealed that the combined percentage area of vascular bundles for each cross-sectional area was inversely related to IVOMD, indicating that structural differences can greatly affect the digestibility of the grass (Schank et al., 1973).

In a review of literature, Quesenberry et al. (1984) reported that Floralta outyielded 'Redalta', 'Greenalta', and 'Bigalta' limpograsses in small plot clipping trials. The IVOMD of Floralta was superior to Redalta and Greenalta and comparable to Bigalta. Quesenberry et al. (1984) noted that persistence of Floralta was superior to that of Bigalta under grazing.

Establishment

Pasture establishment is defined as the sequence of events that occurs from the time the seed is sown until such time that the species are in a position to contribute substantially and permanently to pasture production (Cook and Lowe, 1977). Cook (1980) divided pasture establishment into two phases: germination and emergence, followed by seedling growth and survival. He stated that germination and emergence of tropical pasture species are primarily dependent on microenvironmental factors affecting seed water balance and on the length of time that the soil surface remains wet relative to the germination rates of the species being sown. Further, competition between resident vegetation and the establishing seedlings for nutrients and moisture is seen as the major factor limiting seedling growth and survival.

Aeschynomene

Seedbed preparation. Hedges et al. (1982) reported that establishment by seeding new locations requires orderly management to reduce grass competition. Aeschynomene can be planted on cultivated land or on very closely mowed or grazed sods (Hedges et al., 1982; Chambliss, 1982). Chambliss (1982) noted that aeschynomene may be broadcast seeded or planted with a precision planter. When broadcast seeding into an established grass pasture, the sod should be cut with a medium to light weight disk or chopper before seeding.

This practice exposes soil so that seed can come in direct contact with it when planted. Hodges and McCaleb (1972) also reported that successful establishment has been obtained on sods when the seed was uncovered, but a light disking or chopping is recommended to put the seed in contact with soil. Further, when seeding on cultivated land, the area should be rolled and disked to give minimum coverage (Hodges and McCaleb, 1972; Hodges, 1977). Hodges and McCaleb (1972) concluded that aeschynomene has been planted on extensive areas with growth being vigorous in many cases. However, early summer drouth, excessive grass competition, and premature grazing have limited the success of some plantings (Hodges and McCaleb, 1972).

Sollenberger and Quesenberry (1985) studied aeschynomene establishment in Floralta limpograss sods. These small plot studies suggested that soil moisture at seeding, rainfall within approximately 10 days of seeding, and control of grass competition were most critical in determining success or failure. Subsequent legume dry matter (DM) harvested was greater for seedbed preparation treatments that minimized limpograss competition. A successful seedbed preparation treatment included light disking, broadcasting the seed and cultipacking.

Hodges and McCaleb (1972) and Hodges (1977) noted that germination of aeschynomene occurs in the spring when soil is moist and daytime temperatures reach 32 °C (90 °F). Hodges (1977) recommended planting of aeschynomene between 1 May and 1 June, around the time when summer rains start. Active vegetative growth seldom begins before 1 to 15 June and it continues into September or until the onset of cool weather.

Seed treatment. Ruelke et al. (1974) evaluated the effects of various methods of seed scarification (of intact pods) on germination, establishment, and production of aeschynomene in a bahiagrass (*Paspalum notatum* Flugge) sod. They found that highest cumulative germination percentage (99%) was obtained from mechanically-scarified seed as compared to 5.5% germination of seed in intact pods. The highest germination from pre-germination heat treatments of seeds in intact pods was 59%, which was obtained following a heat exposure to 55 °C for 24 hours. Hanna (1973) reported that depodding and scarification of seed increased germination from 9 to 78% and 2 to 74% for 1968- and 1970-seed crop, respectively. He propose that the seed coat inhibited water imbibition and/or exchange of gases.

Gomes and Kretschmer (1978) germinated seeds of aeschynomene in incubators set at 30, 38, and 46 °C for 9 hours, alternated with 25°C for 15 hours. They reported that podded aeschynomene seeds showed no response to the treatments. However, depodded aeschynomene germination was increased as temperatures increased.

Although many Florida soils have a natural supply of legume bacteria for aeschynomene, new plantings should be treated with cowpea inoculant to insure good nodulation.

Seeding rates. Chambliss (1982) recommended rates of 5.7 to 11.2 kg ha^{-1} for naked seed and 13.4 to 22.4 kg ha^{-1} for seeds in pods if seeded with a precision planter on a prepared seedbed. However, broadcast seeding requires higher seeding rates, especially when seeds are broadcast on established pasture sods.

When seeding into a limpograss sod, use of a higher aeschynomene seeding rate (14 vs. 7 kg naked seed ha^{-1}) and a seeding method which incorporated seeds into the soil (vs. broadcast seeding) produced larger harvests of both legume and total DM (Sollenberger and Quesenberry, 1985). Middleton (1970) indicated that increasing sowing rates of *Desmodium intortum* ('Greenleaf'), *Macroptilium atropurpureum* ('Siratro') and *Setaria sphacelata* ('Nandi') generally increased their yield, but not proportionally. It also caused a decline in the yield of the associated component, with no overall advantage in terms of total yield of DM or N.

Planting depth. Planting depth is important for optimal germination of seed. When a planting depth greater than 13 mm was used for aeschynomene seedings, seedling emergence was significantly reduced (Hanna, 1973).

Burning prior to seeding. Ruelke et al. (1974) reported that winter burning of mature aeschynomene grown in a bahiagrass sod resulted in significantly larger numbers of established aeschynomene seedlings, higher bahiagrass-aeschynomene DM yields, a greater proportion of aeschynomene in mixture, and a higher yield of aeschynomene digestible organic matter (DOM).

Tang and Ruelke (1977) studied the effect of early burning, late burning, and mowing on the reestablishment of aeschynomene from seed on a bahiagrass sod. They found higher aeschynomene plant densities, DM yields, and yields of DOM when plots were burned compared to others which were mowed.

Herbicides prior to seeding. Kalmbacher et al. (1978) reported that herbicidal suppression of a bahiagrass sod facilitated sod-seeded aeschynomene establishment. Yield, legume coverage, and percentage crude protein (CP) of the mixture increased as degree of sod suppression increased. Also, sod treatment with 2.48, 3.32 or 4.98 kg ha^{-1} of dalapon, or 0.28 kg ha^{-1}

of paraquat combined with burning 48 hours after desiccation, resulted in relatively good legume stands.

Kalmbacher and Martin (1983) compared different techniques of establishing aeschynomene in bahiagrass sods. Grazing bahiagrass to a 3- to 5- cm stubble followed by drilling seed and grazing until aeschynomene was 2.5 cm tall resulted in the greatest number of seedlings, the highest DM yield of aeschynomene and the grass-legume mixtures, and the highest sward CP and digestibility. These data indicate that grazing was the most practical and successful method of removing and controlling the bahiagrass canopy during legume establishment, and herbicides, while effective, are too expensive for pasture use in cow-calf operations.

Hodges and McCaleb (1972) reported that cultivated land that has been seeded should be left ungrazed as soon as germination begins. Grass may begin to crowd the legume plants, but aeschynomene will reach above the grass if given time to grow. The effect of stubble height (7.5 vs 15 cm) of a limpograss sod at seeding on germination of aeschynomene was studied by Sollenberger et al. (1987a). Stubble height did not affect germination or early seedling survival, but subsequent legume DM accumulation tended to be higher for the 7.5-cm treatment. Further, continued grazing of the grass until aeschynomene seedlings were 5 cm tall decreased grass competition for the seedlings and improved legume performance.

Limpograss

Floralta produces few seeds and is thus vegetatively propagated. Ruelke et al. (1979) established Redalta, Bigalta, and Floralta from vegetative sprigs using three different planting techniques: 1) broadcasting the sprigs on the surface, 2) sprigging followed by light disking, and 3) sprigging followed by light disking followed by cultipacking. They found that denser stands, earlier production, and higher second year DM yields were obtained when planting material was sprigged followed by disking (to partially cover the stems) and cultipacking (to make firm contact between sprigs and the soil). Bigalta and Floralta were superior to Redalta in establishment year ground cover and DM harvested.

Forage Production

Aeschynomene

Mislevy et al. (1981) conducted a harvest frequency and cutting height study of aeschynomene at Ona, Florida. Aeschynomene was cut when plants reached 30, 60, or 90 cm, and plants were cut to leave 8- or 18-cm stubble heights. Regrowth was cut when plants reached 30, 60, or 90 cm. It was indicated that removal of the initial harvest of aeschynomene when plants were 30 cm tall and regrowth at 90 cm resulted in highest DM yields (3.55 Mg ha^{-1}). Also, Kalmbacher and Mislevy (1978) reported higher CP and DOM yield when aeschynomene was first cut at 30 cm and regrowth was cut at 90 cm. Mislevy et al. (1981) reported that plants harvested at the 30-cm initial and 30-cm regrowth heights tillered profusely, allowing four harvests during the season. They concluded that this frequent 30-30 harvest system appeared to closely simulate grazing. Similarly, Gildersleeve (1982) reported that pastures grazed early showed vigorous regrowth throughout the season.

Chambliss (1982) recommended that grazing of aeschynomene be initiated when plants are 45 to 60 cm tall. He suggested rotational grazing for most efficient utilization. If reseeding is needed, stockin rates should be reduced in late September and early October.

Sollenberger et al. (1987a) reported that initiating summer grazing of limpograss-aeschynomene association when aeschynomene was 60 or 90 cm tall maximized seasonal legume DM accumulation. However, earlier grazing (20 cm) resulted in more uniform accumulation of total and aeschynomene DM throughout the season, higher efficiency of grazing, more vigorous legume regrowth, and a trend toward greater total herbage consumption.

Kretschmer and Snyder (1981) compared yields of aeschynomene, 'Siratro' (*Macroptilium atropurpureum* Urb.) and 'Florida' carpon desmodium (*Desmodium heterocarpon* L.) at 20 and 60 kg ha^{-1} of P (2000 kg ha^{-1} of lime). In the establishment year, production of aeschynomene was better than that of Siratro and of carpon desmodium, but it was much less in June of the subsequent year. The response of aeschynomene to P at either 20 or 60 kg ha^{-1}, however, was greater than that of carpon desmodium at either of the two rates.

Sollenberger and Quesenberry (1985) found aeschynomene contributions of 3.9 Mg ha^{-1} in Floralta limpograss sods from April seedings and they concluded that in years when climatic conditions are favorable the productive period of the legume may be lengthened by seeding prior to onset of summer rains.

Pitman (1983) and Pitman et al. (1985) reported slightly shorter grazing periods for aeschynomene-bahiagrass pastures than for bahiagrass pastures. Bahiagrass pastures fertilized at 224 kg ha^{-1} N had a higher carrying capacity (CC) than unfertilized bahiagrass-aeschynomene pastures. The CC from bahia-aeschynomene pastures was similar to that of bahiagrass pastures fertilized at 56 kg ha^{-1} N.

Limpograss

Ruelke and Quesenberry (1983) studied the effects of fertilization timing on the yields, seasonal distribution, and quality of limpograss forage. They reported that applications of 75 kg ha^{-1} of N in early February to mid-March increased early spring forage production more than applications of 75 kg ha^{-1} of N applied in early April. In 1982, early spring yields, following application of N in early March, were nearly double the yields obtained from the late March fertilization.

Ruelke and Quesenberry (1983) studied late fall response of limpograss to N fertilization. They found that following an early August application of N (75 kg ha^{-1}) there was a rapid increase in forage yield until late September, after which the yield reached a plateau until first frost. They noted that CP dropped continuously with maturity and by late September the forage available contained less than the minimum concentration required for maintenance of animals. Similar results were found in 1982.

Kretschmer and Snyder (1979) reported that during a 24-week period, increasing cutting interval (CI) from 4 to 12 weeks (total of 336 kg ha^{-1} of N applied) resulted in higher Bigalta total yields, lower forage IVOMD and CP concentrations, and higher yields of DOM. They also found that delaying fall fertilization from 17 September or 1 October until 29 October resulted in greatly reduced forage production when harvested on 17 December. However, the IVDOM and CP concentration increased as fertilization was delayed. In many cases, the CP concentrations observed were below the level thought to be necessary for maximum voluntary intake of forage by ruminants.

Christiansen et al. (1981) studied nonstructural carbohydrate physiology of Floralta limpograss. Cutting frequencies (CI) of 2.5, 5, 10, 15, and 25 weeks were imposed on limpograss swards in the field to establish various levels of reserves. They subsequently measured the reserve energy pool by quantifying etiolated regrowth yields of plant cores placed in a darkroom. Limpograss showed no treatment effects on weight of etiolated shoots in two experiments; however, when data were analyzed with covariance techniques using stem base weights as a covariable, a treatment effect was detected. The shortest CI resulted in the lowest shoot weights (0.28 g pot^{-1}) and the longest CI in the highest shoot weight (0.42 g pot^{-1}).

Quesenberry et al. (1981) evaluated eight genotypes of limpograss at four frequencies of grazing (3, 5, 7, and 9 weeks). They found poor persistence using the 3-week grazing frequency. Seasonal yields were similar at the 5- and 8- week grazing frequencies. Of the Hemarthria genotypes studied, the tetraploid genotypes Bigalta and Floralta had markedly higher yields at 5- and 9-week grazing frequencies. Floralta was generally the highest yielding entry at all grazing frequencies and was not significantly lower in IVOMD than Bigalta. Commenting on data from the same study, Quesenberry et al. (1984) noted that Floralta persistence was superior to Bigalta and PI 364874, and comparable to Redalta when compared at the different grazing frequencies. A major factor contributing to the persistence of Redalta was poor animal acceptability. They mentioned that Floralta did not show evidence of being unpalatable and plots were generally grazed as closely as Bigalta. In a companion mob grazing experiment, Floralta had consistently higher percentage ground cover than did Bigalta at grazing frequencies of 3, 6, 9, and 12 weeks. However, frequent close defoliation of Floralta may result in increased weed competition. Dry matter yields for Floralta were higher than those for Bigalta at all grazing frequencies.

Forage Quality

Minson (1980) noted that the main factor controlling growth rate and milk production of cattle is net energy

(NE) intake. There are three primary factors controlling the intake of NE: the quantity of food energy eaten, the proportion of each unit of food that is digested, and the efficiency of utilization of the products of digestion. On pasture, intake is affected by the chemical and physical properties of the forage, which in turn are related to soil conditions, climate, pasture species, stage of growth, and part of the plant being eaten. Milford and Minson (1965) found a poor relationship between intake and digestibility. They found that the intake of grass species declined rapidly when the CP concentration of consumed feed fell below 7 dag kg^{-1} DM.

Aeschynomene

Forage Responses. *Aeschynomene* CP and IVDOM concentrations were studied by Gildersleeve (1982). She evaluated several plant introductions from four species. Leaf-seed CP was 15 to 30 dag kg^{-1} for all accessions compared to 10 dag kg^{-1} for stem CP. Gildersleeve (1982) also reported IVDOM of 65 to 75 and 30 to 40 dag kg^{-1} OM for leaf-seed and stem fractions, respectively.

In a study comparing 342 accessions of the genus *Aeschynomene*, Kretschmer and Snyder (1981) reported wide morphological and agronomic diversity of *A. americana*. They indicated that in June, CP concentration of aeschynomene (18.8 dag kg^{-1} OM) was highest and IVOMD among the best (52.1 dag kg^{-1} OM) when compared to other accessions. These values ranged from 10.8 to 18.8 dag kg^{-1} OM and 36.9 to 63.8 dag kg^{-1} OM, respectively, among the accessions analyzed.

Quesenberry and Ocumpaugh (1981) evaluated over 200 accessions of Aeschynomene and found that plant N concentration was generally inversely related to OM yield, but some accessions had single harvest yields of greater than 2000 kg ha^{-1} and CP concentration greater than 20 dag kg^{-1}.

Aeschynomene leaves had CP and IVDOM concentrations of 25 dag kg^{-1} OM and 70 dag kg^{-1} OM (Sollenberger et al., 1987b). Mislevy et al. (1981) reported that harvesting plants frequently and at an immature growth stage (30-cm initial and 30-cm regrowth) provided lower OM yields (2500 kg ha^{-1}), but higher quality forage (averaging 17.5 dag CP kg^{-1} OM and 70 dag IVDOM kg^{-1} OM). Kalmbacher and Mislevy (1979) reported higher CP and DOM yields when aeschynomene was first cut at 30 cm and regrowth was cut at 90 cm. When initially cut at 30 cm the CP concentration was 18.5 dag kg^{-1} OM compared to 15.1 dag kg^{-1} OM for plants first cut at 90 cm.

Gildersleeve (1982) sampled pastures pre- and postgraze to quantify animal preference. Results showed differences between pregraze leaf-seed and stem fractions of greater than 30 dag kg $^{-1}$ DM for IVDOM and 15 dag kg $^{-1}$ DM for CP. It was noted that forage quality of postgraze residue resembled that of the pregraze stem fraction.

Sollenberger et al. (1987b) reported that forage quality of a limpograss-aeschynomene association was highest when grazing was initiated at 20 cm. Crude protein concentration was generally above 7 dag kg $^{-1}$ DM when percentage legume in the total herbage accumulated was 15% or greater.

Kalmbacher et al. (1981) determined plant K, Ca, Mg, P, Fe, Zn, Mn, and Cu concentrations in 30-, 60- and 90-cm growth of aeschynomene. Comparisons of mineral concentration of aeschynomene with requirements of growing calves and yearlings indicated that it should meet animal needs without supplementation. An exception was the Cu concentration which was slightly below the 4 mg kg $^{-1}$ level recommended by the NRC.

Animal Performance. Hodges et al. (1974) supplemented a digitgrass pasture system with an aeschynomene-bahiagrass pasture. Calf weaning weights were similar for this improved system when compared to digitgrass pastures alone. However, an average of 82% of the cows weaned calves for the system including aeschynomene, and 67% weaned calves when grazing digitgrass alone.

Bishop et al. (1985) seeded 1.2 kg of dehulled aeschynomene seed in strips on a prepared seedbed. The strips included approximately 30% of a 2.4 ha area. The interstrip areas were seen to 'Callide' rhodesgrass (Chloris gayana Kunth). In the fourth summer after establishment of this pasture, five 15-month-old steers grazed the pasture for 187 days and gained 0.8 kg $head^{-1}$ day^{-1}. They indicated that these gains were higher than those recorded from other sown pastures for this period.

Spicer et al. (1982) conducted two trials to evaluate aeschynomene haylage supplemented with protein or energy. They concluded that harvesting aeschynomene at the late bloom stage resulted in a forage of low quality which required supplementation to meet protein and energy requirements for growing steers.

Hodges et al. (1976) reported higher summer average daily gains for steers grazing 'Pensacola' bahiagrass-aeschynomene (0.45 kg) pastures when compared to Pensacola bahiagrass (0.28 kg) pastures fertilized with N. Similar trends were observed by Pitman (1983). He reported ADG's of 0.58, 0.48, and 0.43 kg $head^{-1}$ day^{-1} for animals grazing bahiagrass-aeschynomene and bahiagrass fertilized with 224 and 56 kg N ha^{-1}, respectively. Also, Hodges (1977) reported daily gains of 0.55 kg for yearling heifers when grazing aeschynomene from 26 July to 18 October.

Limpograss

Forage Responses. Moore et al. (1981) studied digestibility and intake of 12 cultivars of tropical grasses at different stages of maturity. In general, forage quality (TDN intake) declined with maturity and there was little difference among cultivars at 8 weeks of regrowth. At that maturity TDN intake of all cultivars was approximately equal to the maintenance energy requirement. They further reported that 'Coastcross-1' bermudagrass (*Cynodon dactylon* L.) and several bahiagrasses were generally lower in overall quality than limpograss.

Ruelke and Quesenberry (1983) studied the effect of fertilization date (17 Feb., 16 Mar., or 14 Apr., 1981, and 1 March or 29 March, 1982) on CP concentration of Floralta limpograss. They found that N application dates affected limpograss CP, and highest concentrations were found in forage fertilized in mid March in 1981 and late March application in 1982. These plots were harvested on 30 Mar., 14 Apr., 28 Apr., or 12 May, 1981, and on 12 Apr., 21 Apr., 5 May, or 25 May, 1982. In both years there was a corresponding decline in CP concentration as date of harvest was delayed.

Sollenberger et al. (1987b) reported that, when pastures were grazed rotationally with a defoliation interval of 5 weeks, limpograss (grown in association with aeschynomene) CP concentration was less than 4.0 dag kg^{-1} OM. Under similar defoliation intervals, Geiger (1986) reported that CP concentration of handplucked Floralta (fertilized with N) samples was lower than that found in Pensacola bahiagrass samples (8.5 and 11.5 dag kg^{-1}, respectively). The IVDOM of those samples was 65.7 and 59.8 dag kg^{-1} OM for Floralta and Pensacola, respectively.

Quesenberry and Ocumpaugh (1982) investigated changes in mineral composition with maturity of autumn-winter stockpiled limpograss. As plants matured, K and P concentration decreased to levels below those recommended by the National Research Council (NRC) for ruminants. Calcium concentration frequently fell below the recommended level for lactating beef cows but Mg concentration did not. They concluded that mineral supplementation would be required for cattle feeding on 2- to 3-month-old limpograss.

In another study, Quesenberry and Ocumpaugh (1980) noted differences in Redalta, Greenalta, and Bigalta forage quality when stockpiled in the fall. They found that Bigalta had higher IVOMD than Redalta and Greenalta at all sampling dates in 2 years. The decline in CP occurred rapidly in all grasses, and by the time the grasses would be consumed as stockpiled forage, CP had dropped below the level necessary to maintain zero N balance in the grazing animal. However, no meaningful differences in CP among grasses were observed.

Minson and Milford (1967) used sheep to examine the effect of varying quantities of lucerne and white clover on voluntary intake of 12-week-old 'Pangola' digitgrass. The proportion of the legume in the diet varied from 0 to 100% so that supplementary and replacement effects of the legume could be distinguished. They reported low voluntary intake when sheep were offered mature grass. By including 10 to 20% legume in the diet the voluntary intake of Pangola increased, probably due to the elimination of a CP deficiency. Once any deficiency was overcome, further increases in the quantity of legume fed caused a depression in the voluntary intake of Pangola due to direct replacement by the legume. As the proportion of legume in the diet increased from 0 to 100% there was an increase in the voluntary intake of the entire diet, an increase in the DM and CP digestibilities, and a corresponding reduction in liveweight losses.

Animal Performance. Quesenberry et al. (1984) reported mean CC of 3 animals ha^{-1} for Pensacola bahiagrass versus 4 animals ha^{-1} for Floralta. Average daily gains were similar on Floralta and on Pensacola bahiagrass (0.35 and 0.33 kg, respectively); however, the increased CC and additional calendar days of grazing resulted in an almost twofold difference in total gain per ha for Floralta. The second year of this experiment again showed that animal days per ha and average number of animals per ha were greater for Floralta limpograss than Pensacola bahiagrass, and ADG was not different for the two systems (0.50 for Pensacola vs. 0.43 for Floralta). It was noted that in this year the Floralta pastures were underutilized in the early part of the grazing season resulting in lower quality forage and thus lower ADG in late summer and fall. They suggested that Floralta pastures should be grazed sufficiently close in the early summer to prevent a build up of mature stems near the soil. Quesenberry et al. (1984) also reported that Floralta limpograss is well adapted to a tropical environment with alternating wet and dry seasons and shows promise for animal gains similar to guineagrass (*Panicum maximum* Jacq.) under similar management conditions. Targas et al. (1982) reported good ADG's of 0.5 kg on limpograss pastures stocked with 5 animals ha^{-1} for a grazing period of 350 days.

Gieger (1986) reported that total seasonal liveweight gains ha^{-1} under rotational grazing and high N rates were 702 kg for animals grazing Floralta limpograss and 494 kg for those on Pensacola bahiagrass. The difference was mainly due to higher forage yields from Floralta pastures. She noted that the "summer slump" period for Floralta corresponded with the period when its CP concentration fell below 7 dag kg^{-1} DM. Over the season, neither CP nor IVOMD was correlated with ADG.

Pests and Diseases

Aeschynomene

Sonoda and Lenne (1979) listed diseases associated with the genus *Aeschynomene*. Fungal pathogens include the genera *Uredo* and *Colletotrichum*. Viral diseases include tobacco streak virus and legume little leaf disease.

Kretschmer et al. (1980) reported that Florida common aeschynomene was resistant to root-knot nematodes (*Meloidogyne* spp.). Bullock and Kretschmer (1982) reported that aeschynomene is subject to attack by the noctuid defoliators *Selenis monotropa* Grote, the velvetbean caterpillar (*Anticarsia gemmatalis* Hubner), the tobacco budworm (*Heliothis virescens* [F.]), and the gelechiid leafbinder (*Evippe* sp.). They also reported that some biological control is provided by the spiders *Misumenops celer* (Hentz) and *M. bellulus* (Banks), the parasitic wasp Euplectrus comstockii Howard, and the entomophagous fungus Nomuraea rileyi (Farlow) Samson. It was concluded that reduction in leafbinding with the use of the insecticide "diflubenzuron" can improve seed production by as much as 350%. Until insect resistant cultivars are discovered or developed, insecticides will be necessary to prevent leafbinding and assure optimum seed production in Aeschynomene.

Kalmbacher et al. (1979) reported that snails (Polygyra cereolus Muhlfeld) may consume aeschynomene seedlings and cause poor legume stands. They found that burning bahiagrass after desiccation with paraquat killed 98% of these snails.

Limpograss.

Quesenberry et al. (1984) stated that the armyworm complex, which attacks many tropical grasses in Florida, can cause severe damage in isolated circumstances; however, damage appears to be no worse on Floralta than most other tropical grasses.

In a series of sting nematode (Belonolaimus longicaudatus Rau) tolerance trials, Quesenberry and Dunn (1978) found that Floralta was significantly poorer in sting nematode tolerance than the most tolerant line. It was not significantly different, however, from the released cultivars Bigalta and Redalta in sting nematode tolerance. However, this nematode does not seem to be a problem on flatwood soils where limpograss is best adapted (Quesenberry et al., 1978).

Oakes (1978) reported that Floralta was significantly less susceptible to the yellow sugar-cane aphid (Sipha flava Forbes) than Pangola digitgrass but similar in resistance to Greenalta. However, Crowder and Chheda (1982) reported that the aphid attack leaves and stems of Pangolagrass and Hemarthria species and may reduce herbage yields 30% or more. They indicated that plants infested by aphids may turn yellow, eventually reddish and sometimes die. According to Quesenberry et al. (1984) no major foliar diseases of Floralta limpograss have been identified.

CHAPTER III
ANIMAL PERFORMANCE AND FORAGE QUALITY IN LIMPOGRASS-NITROGEN AND LIMPOGRASS-AESCHYNOMENE PASTURES

Introduction

The need for efficient animal production is the basis for efforts to improve pasture production and forage quality. Evaluation of grass-legume pastures has been a part of this process in subtropical and tropical regions, since the contribution of high quality forage to animal's diets is realized without the addition of large amounts of nitrogen (N) fertilizer. Also, legumes contribute symbiotically fixed N to the pasture system, thus increasing the efficiency of animal production.

'Floralta' limpograss (*Hemarthria altissima* [Poir.] Stapf et C. E. Hubb.) has been under evaluation in Florida since 1974 and has shown promise because of its high dry matter production and relatively high in vitro organic matter digestibility (Quesenberry et al., 1984). However, animals grazing limpograss (N fertilized) pastures produced low average daily gain, and it was previously suggested (Euclides, 1985; Sollenberger and Quesenberry, 1985; and Gieger, 1986) that low crude protein concentration (less than 5%) in Floralta herbage might be responsible.

Aeschynomene (*Aeschynomene americana* L.), a summer annual legume that grows in Florida, is widely adapted (Hodges et al., 1982) and has high forage quality (Gildersleeve, 1982; Sollenberger et al., 1987b). Gomes (1978) indicated that this forage has potential for use in association with limpograss. Sollenberger et al. (1987b) suggested that the use of aeschynomene may improve animal performance on summer pastures during the "summer slump" period. A grazing study was conducted in 1985 and 1986 to test this hypothesis. The specific objectives of the study were a) to compare average daily gain, carrying capacity, and gain ha^{-1} of limpograss-N (LN) and limpograss-aeschynomene (LA) pastures, b) to compare crude protein concentration and in vitro organic matter digestibility of the forage in both systems, and c) to relate animal performance and measures of forage quality.

Materials and Methods

Experimental Site

The experiment was conducted in 1985 and 1986 at the Forage Evaluation Field Laboratory of the Beef Research Unit (BRU) near Gainesville, Florida. Soils at the BRU are moderately to poorly drained, sandy Spodosols (USDA, 1982) of low fertility, belonging to the Pomona (sandy, siliceous, hyperthermic Ultic Haplaquod) series. Rainfall and temperature profiles are presented for 1985 and 1986 (tables 1 and 2).

Soil Status and Fertilization

Mean soil pH in the pastures used for this experiment in 1985 was 5.7, and Mehlich I extractable P and K were 8.8 and 34.8 mg kg^{-1}, respectively. In 1986, soil pH was 6.0, and P and K levels were 15.5 and 37.3 mg kg^{-1}. Based on soil test results, P and K were broadcast at rates of 60 and 150 kg ha^{-1} in March 1985 on all pastures. In early April 1986, P and K were applied at rates of 40 and 75 kg ha^{-1} on LN pastures, and 50 and 95 kg ha^{-1} on LA pastures. All pastures received 11 kg ha^{-1} of a micronutrient mixture (F-503 Oxide) in both years. Lime was applied at a rate of 1.1 Mg ha^{-1} on the LA pastures and one of the LN pastures in 1985 based on the 1985 soil test. No lime was used in 1986. Nitrogen was split applied (4 times) to the LN pastures at an annual rate of 150 kg ha^{-1} in 1985 and 130 kg ha^{-1} in 1986. Applications were made in the spring (March and April in 1985 and 1986, respectively) and after each grazing period (50, 40, 30, and 30 kg ha^{-1} N in 1985, and 40, 30, 30, and 30 kg ha^{-1} in 1986), except the last of the season.

Table 1. Monthly rainfall during 1995, 1996, and a 70-year period.

	Rainfall (mm)		
Month	1995	1996	70-year
January	31	159	70
February	47	119	94
March	30	90	109
April	119	22	77
May	91	25	90
June	151	159	173
July	227	94	219
August	252	163	210
September	122	105	144
October	205	66	93
November	52	92	49
December	49	97	74
Total	1376	1191	1401

Table 2. Mean, maximum, and minimum temperatures in 1985, 1988, and a 70-year period.

	Temperature (°C)					
	Maximum			Minimum		
Month	1985	1988	70-year	1985	1988	70-year
January	18	18	20	2	3	8
February	22	22	22	8	8	9
March	26	24	24	8	9	12
April	28	25	28	9	8	14
May	32	31	31	15	13	18
June	33	33	32	20	17	21
July	32	33	33	20	21	22
August	32	33	33	21	21	22
September	31	31	32	18	20	21
October	30	27	28	18	18	18
November	27	28	25	14	18	11
December	20	24	21	3	11	8

Pastures

Six Floralta limpograss pastures (1 ha) had been established between 1980 and 1982. These pastures were continuously stocked during the summer grazing seasons through 1983. In 1984, three Floralta pastures were overseeded with aeschynomene and three were fertilized with N for use in a preliminary evaluation of animal performance.

Average daily gain in 1984 (table 3) was higher ($P<0.01$) for LA than for LN pastures, suggesting a higher quality diet for animals grazing LA. Carrying capacity was lower ($P<0.05$) in LA than in LN pastures, indicating higher dry matter production in N-fertilized limpograss. Gain ha^{-1} was not different, but there was a trend towards higher gain ha^{-1} in LA compared to LN pastures. Thus, 1984 data indicate improved animal production in limpograss pastures when aeschynomene is included.

For the current study, conducted in 1985 and 1986, three Floralta pastures were again overseeded with aeschynomene and three were fertilized with N. Pastures were grazed rotationally as in 1984. Each pasture of the two treatments (LA and LN) was divided into six paddocks and a 42-day rotational grazing system was used (7 days grazing and 35 days rest). To limit accumulation of large quantities of mature, stemmy grass

Table 3. Animal performance on limpograss-N (LN) and limpograss-aeschynomene (LA) pastures during August, September, and October 1984.

Item	LN§	LA§
ADG (kg)¥	0.38±0.03	0.69±0.04**
CC¶	28±2	20±2*
Gain ha^{-1} (kg)	270±34	343±41

** Means within the same row differ ($P<0.05$).
* Means within the same row differ ($P<0.01$).
§ Mean responses over 3 vs. 2 replications for LN and LA, respectively.
¥ Average daily gain.
¶ Carrying capacity (100-kg liveweights ha^{-1} day^{-1}).

herbage during the first grazing cycle of 1985 (this cycle was not a part of the experimental period), paddocks 1 through 3, 4 and 5, and 6 were treated as single paddocks and grazed for 1 week each during the 3-week-long cycle. This allowed establishment of low, moderate, and regular grazing pressures, respectively, before initiation of the 7 days grazing, 35 days rest regimen on individual paddocks. In 1986, grazing was initiated when the grass canopy was shorter than in 1985, and the 42-day cycle was used from the start. Mineral supplementation was available to animals on an ad libitum basis.

Legume Establishment

Aeschynomene is generally planted in early June, at the onset of summer rains in Florida. To lengthen the period when animal and forage responses could be measured, aeschynomene pastures were seeded in the first week of May. This lengthened the grazing period and provided a more detailed measure of animal and forage responses. Irrigation was used as needed to facilitate legume establishment.

Establishment of each pasture was done in two stages, with one-half of the pasture being seeded in early May and one-half seeded 3 weeks later. This approach was taken to reduce maturity differences between herbage in the first and sixth paddocks in the rotational grazing system to be used.

Prior to planting aeschynomene, grass in the pastures to be seeded was grazed closely and disked lightly in late spring. Aeschynomene was then seeded at a rate of 22 kg ha^{-1} using a cultipacker seeder. The seed had been dehulled, scarified, and inoculated with cowpea inoculant. Pastures were irrigated as needed (one or two times at approximately 2.5 cm, weekly) until seedlings were 5 cm tall (approximately 4 weeks after seeding for the first half). In the second half of the pastures, irrigation was required for only 2 weeks, since summer rains began soon after seeding. To control grass competition during aeschynomene establishment, pastures were grazed two to three times for 8 hours at a stocking rate (SR) of 20 animals ha^{-1} . Grazing continued until seedlings reached the two-leaf plus 2-week stage (Sollenberger et al., 1987a).

Grazing of the association was initiated in late June when aeschynomene was 20 cm tall. The experimental period, during which both treatments were being grazed, started in late June and ended in the beginning of November in both 1985 and 1986.

Animals

Four crossbred yearling steers (Bos spp.) were assigned as testers to each pasture (table A-15). Put and take animals were added and taken off to maintain an "optimal" grazing pressure (Mott and Lucas, 1952; between 1200 and 1600 kg ha^{-1} of residual forage remaining after each grazing period; table A-16). Average tester weight at the start of the experimental period was 312 and 315 kg in 1985 and 1986, respectively. Animal weights (testers and put and takes) were taken at 3-week intervals after the animals were shrunk for 16 hours without feed or water. Put and take animals were also weighed when added or taken off pasture within the 3-week interval. Weight data of the testers were used to calculate average daily gain (ADG) for a specific treatment. Carrying capacity was calculated using both tester and put and take animals, and it is expressed in units of 100-kg liveweights ha^{-1} day^{-1} (Mott and Lucas, 1952). The liveweight gain ha^{-1} was calculated by first dividing the number of 100-kg liveweights ha^{-1} day^{-1} by the 100-kg liveweight of the average tester to obtain a value for animals ha^{-1} day^{-1} that was adjusted for the weight of the average tester. Average daily gain and the adjusted value for animal days ha^{-1} were then multiplied.

Forage Sampling

Pasture samples were taken before and after grazing in every other paddock (paddocks 1, 3, and 5 in LN, and 2, 4, and 6 in LA pastures) for each replication in both pasture systems. A double sampling technique was used to quantify herbage mass and to determine botanical composition (percentage aeschynomene, limpograss, and weeds). This technique combined visual estimates made by a single observer, and actual values determined by cutting forage to ground level and hand separating the fresh herbage (Stockdale, 1984).

In each paddock, three double sampling sites (0.5 m^2) were selected (not at random) that would represent the range of the response variables (herbage mass, percentage aeschynomene, limpograss, and weeds) present in a given pasture. Visual estimates of the response variables were then recorded. The forage was then clipped and hand separated into three fractions (aeschynomene, limpograss, and weeds). These samples were dried at 60 °C for 48 hours, and percentage of each component was calculated. Actual values (from sampled sites within a date) for a given response variable were regressed on visual estimates. The regression equation (with intercept) was used to adjust the mean of 30 visual estimates that were taken at randomly selected locations in each paddock. The adjusted mean is the reported value for each response variable.

Handplucked aeschynomene and Floralta samples were collected whenever pregraze whole plant samples were taken. The objective of this procedure was to select herbage which represented that consumed during grazing.

Pregraze whole canopy forage data are reported for the two systems. These data were calculated by adding the quantity of CP and IVDOM of each botanical component within each pasture system and dividing by total DM and total OM, respectively.

Forage Analysis

All forage samples were ground (1-mm size) using a Wiley mill and analyzed for N and IVDOM. Nitrogen concentration was determined using a modification of the aluminum block digestion procedure (Gallaher et al., 1975). Sample weight was 0.25 g and 3.2 g of catalyst (9:1 K_2SO_4:$CuSO_4$) was added. Digestion was conducted for 4 hours at 400°C using 10 ml H_2SO_4 and 2 ml H_2O_2. Ammonia in the digestate was determined by semiautomated colorimetry (Hambleton, 1977), and CP (DM basis) was calculated as N x 6.25. In vitro digestible organic matter concentration (DM basis) was determined using a modified two-stage IVDOM procedure (Moore and Mott, 1974).

Statistics

Treatment differences were analyzed using least-squares analysis of variance (computer program was Proc GLM; SAS, 1979). The design was completely randomized, so the model included treatments (LA vs LN), pasture(treatment), period, and the period x treatment interaction. For tests within specific periods, only treatment and pasture(treatment) were included in the model. Least-squares means and standard error of the means are reported (appendix tables). Aeschynomene responses over the grazing season were established using a stepwise regression procedure (Ryan et al., 1982) to find the highest order of regression (P<0.05). The regression equation was then recalculated using the highest significant order.

Results

Responses measured during the experimental periods of 1985 and 1986 include i) the animal responses, i.e., average daily gain (ADG), carrying capacity (CC) and gain ha^{-1} (GH) and ii) the forage responses, i.e., digestible organic matter (IVDOM) and crude protein (CP) concentration in the pregraze canopy, percentage aeschynomene in the pregraze canopy, and aeschynomene and limpograss CP and IVOOM (whole plant and handplucked).

Average Daily Gain

Average daily gain was higher in both 1985 ($P<0.01$) and 1986 ($P<0.05$) for LA (0.55 vs 0.27 and 0.85 vs. 0.54 kg head^{-1} day^{-1}, respectively; figs. 1 and 2; tables A-1 and A-2) compared to LN pastures. In 1985 there was also a treatment x period interaction ($P<0.01$). Gain during all four, 3-week periods through 18 Sept. 1985 was higher ($P<0.01$) for LA when compared to LN pastures, however, no differences were detected for the last 2 periods. In 1986 there was no treatment x period interaction, and both treatments reached their minimum ADG (0.6 vs 0 kg head^{-1} day^{-1} for LA and LN, respectively) in the 3-week period ending on 24 September.

Characteristics of the Pregraze Canopy

Digestibility. Mean IVOOM concentration of the pregraze canopy was higher in 1985 (figure 3; table A-13; $P<0.025$) for LA pastures (56.6 decagrams (dag) kg^{-1} OM) than for LN pastures (50.2 dag kg^{-1} OM). There was a treatment x day interaction ($P<0.01$), but at only one date before 24 Sept. 1985 were treatments not different ($P>0.1$). The digestibility of pregraze LN pastures

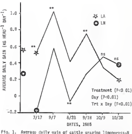

Fig. 1. Average daily gain of cattle grazing limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985. Treatments are different (**, P<0.01) or not different (ns) at a given date.

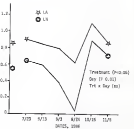

Fig. 2. Average daily gain of cattle grazing limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986.

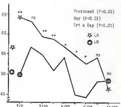

Fig. 3. In vitro digestible organic matter (IVDOM) concentration in the pregraze canopy in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985. Treatments are different (*, $P<0.05$, or **, $P<0.01$) or are not different (ns) at a given date.

dropped dramatically in September, then increased toward the end of the grazing season. In 1986 (figure 4; table A-14), canopy digestibility was not different between treatments, and there was no treatment x day interaction. With the exception of two sampling periods, however, there was a trend favoring LA pastures.

Crude Protein. In 1985, CP concentration in the pregraze canopy was higher ($P<0.05$) for LA pastures (7.9 dag kg^{-1} DM) than for LN pastures (6.1 dag kg^{-1} DM; figure 5; table A-13). No treatment x day interaction was detected. In 1986 (figure 6; table A-14), there was no treatment effect, however, there was a treatment x day interaction ($P<0.01$). On 7 Oct. 1986, CP in the pregraze canopy was higher for LA ($P<0.01$) than for LN pastures, and on 1 July, CP was lower for LA pastures ($P<0.1$).

Percentage Legume. In 1985, percentage legume in the pregraze canopy increased over the season and reached its maximum in early September (figure 7; table A-17). In 1986, percentage legume increased linearly throughout the season. Maximum percentage legume in both years was less than 40%.

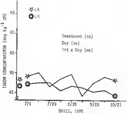

Fig. 4 In vitro digestible organic matter (IVDOM) concentration in the pregraze canopy in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986.

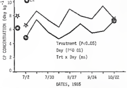

Fig. 5 Crude protein (CP) concentration in the pregraze canopy in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985.

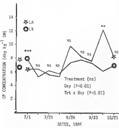

Fig. 6. Crude protein (CP) concentration in the pregraze canopy in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986. Treatments are different (**, P<0.01, or ***, P<0.1) or are not different (ns) at a given date.

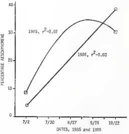

Fig. 7. Aeschynomene as a percentage of the herbage mass in the pregraze canopy in limpograss-aeschynomene (LA) pastures in 1985 and 1986

Characteristics of Forage Components

Aeschynomene Digestibility. Aeschynomene pregraze IVDOM concentration (whole plant) showed a similar seasonal response (linear) in both 1985 and 1986 (figure 8 and 9; table A-17). As the grazing season progressed, IVDOM decreased. Aeschynomene postgraze IVDOM concentration response was quadratic (figure 8 and 9; table A-17), and decreased over the season. Aeschynomene handplucked IVDOM concentration was similar in both years and remained generally constant until September, after which it decreased to its minimum level at the last sampling date.

Aeschynomene Crude Protein. Aeschynomene pregraze CP concentration (whole plant) decreased over the season in 1985 (figures 10 and 11; table A-17), but in 1986 there was no seasonal effect. Aeschynomene postgraze CP concentration (whole plant) decreased as the season progressed (figures 10 and 11; table A-17), and it was generally about 5 dag kg^{-1} DM lower than that in pregraze whole plant material. Aeschynomene handplucked CP increased from the beginning of the season reaching 27 dag kg^{-1} DM toward the end of August, and it decreased as the season progressed further.

Limpograss Digestibility. Limpograss pregraze IVDOM concentration (whole plant) in 1985 was higher ($P<0.1$) for LA compared to LN (58.6 vs. 55.1 dag kg^{-1} OM)

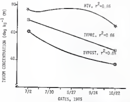

Fig. 8. In vitro digestible organic matter (IVDOM) concentration in pregraze aeschynomene whole plants (IVPRE), postgraze aeschynomene whole plants (IVPOST), and handplucked aeschynomene (HIV) in limpograss-aeschynomene pastures in 1985.

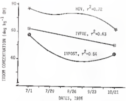

Fig. 9. In vitro digestible organic matter (IVDOM) concentration in pregraze aeschynomene whole plants (IVPRE), postgraze aeschynomene whole plants (IVPOST), and handplucked aeschynomene (HIV) in limpograss-aeschynomene pastures in 1986.

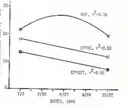

Fig. 10. Crude protein (CP) concentration in pregraze aeschynomene whole plants (CPPRE), postgraze aeschynomene whole plants (CPPOST), and handplucked aeschynomene (HCP) in limpograss-aeschynomene pastures in 1995.

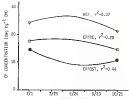

Fig. 11 Crude protein (CP) concentration in pregraze aeschynomene whole plants (CPPRE), postgraze aeschynomene whole plants (CPPOST), and handplucked aeschynomene (HCP) in limpograss-aeschynomene pastures in 1986.

pastures (figure 12; table A-9). In 1986 (figure 13; table A-10), there was no treatment difference (51.2 vs. 50.4 dag kg OM for LA and LN pastures, respectively), and there was no treatment x day interaction in either year. In 1985, limpograss IVDOM concentration decreased over the season, but in 1986 there was no seasonal effect.

In both 1985 and 1986, limpograss handplucked IVDOM concentration was not different (figures 14 and 15; tables A-11 and A-12) between treatments (58.2 and 56.4 dag kg^{-1} OM for LA and LN pastures, respectively). Only in 1986 was there a treatment x day interaction ($P<0.1$). Limpograss handplucked IVDOM tended to be higher early in the season and in the late summer to early fall period for LA pastures.

Limpograss Crude Protein. Limpograss pregraze whole plant CP was not different between LA and LN pastures in 1985 or 1986 (4.5 and 4.7 dag kg^{-1} DM in 1985 and 5.8 and 5.3 dag kg^{-1} DM in 1986 for LA and LN pastures, respectively; figures 16 and 17; tables A-7 and A-8). In 1985 there was no treatment x day interaction, but the interaction was important in 1986 ($P<0.05$). In 1986, limpograss-N pastures tended to have higher grass CP until the last periods of the season.

Limpograss handplucked CP was higher ($P<0.05$) for LN pastures compared to LA pastures (9.2 vs. 7.4 dag kg^{-1}

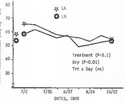

Fig. 12. Limpograss pregraze (whole plant) in vitro digestible organic matter (IVOOM) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985.

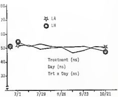

Fig. 13. Limpograss pregraze (whole plant) in vitro digestible organic matter (IVDOM) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986

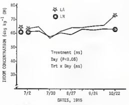

Fig. 14. Limpograss (handplucked) in vitro digestible organic matter (IVDOM) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985.

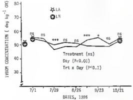

Fig. 15. Limpograss (handplucked) in vitro digestible organic matter (IVDOM) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986. Treatments are different (*, $P<0.05$, or ***, $P<0.1$) or are not different (ns) at a given date.

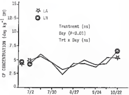

Fig. 16. Limpograss pregraze (whole plant) crude protein (CP) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985

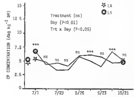

Fig. 17. Limpograss pregraze (whole plant) crude protein (CP) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986. Treatments are different (***, $P<0.1$) or are not different (ns) at a given date.

DM in 1985, and 6.8 vs. 7.4 dag kg^{-1} DM in 1986; figures 18 and 19; tables A-11 and A-12). Only in 1986 was there a treatment x day interaction (P<0.05). On the first five sampling dates of the grazing season LN pastures had higher (P<0.1) CP in handplucked grass, but during the last two sampling dates there was a trend favoring grass CP in LA pastures.

Carrying Capacity

Carrying capacity expressed as 100-kg liveweights ha^{-1} day^{-1}, was not different between LN and LA pastures (17.9 vs. 14.8 in 1985, and 20.7 vs. 16.8 in 1986, respectively; figures 20 and 21; tables A-3 and A-4). In both years, however, there was a treatment x period interaction (P<0.01 and P<0.05 in 1985 and 1986, respectively). In the first three, 3-week periods in 1985, LN pastures had a higher CC than did LA pastures (P<0.1), but during the last period CC was higher on LA pastures. Only during the first 3-week period in 1986 was CC higher for LN than for LA pastures (P<0.01).

Gain per Hectare

In 1985, gain ha^{-1} (figure 22; table A-5) was higher (P<0.01) for LA pastures (294 kg) when compared to LN pastures (156 kg) over the 18-week experimental period. There was a treatment x period interaction (P<0.01) in

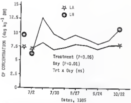

Fig. 19. Limpograss (handplucked) crude protein (CP) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985

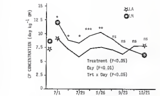

Fig. 19. Limpograss (handplucked) crude protein (CP) concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986. Treatments are different (*, P<0.05, or **, P<0.01, or ***, P<0.1) or are not different (ns) at a given date

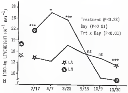

Fig. 20. Carrying capacity (CC) of limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985. Treatments are different (*, $P<0.05$; or ***, $P<0.1$) or are not different (ns) at a given date.

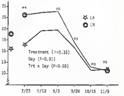

Fig. 21. Carrying capacity (CC) of limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986. Treatments are different (**, P<0.01) or are not different (ns) at a given date.

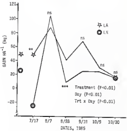

Fig. 22 Gain ha^{-1} of limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985. Treatments are different (**, $P<0.01$, or ***, $P<0.1$) or are not different (ns) at a given date.

1985. Only during two periods (17 July and 28 August) were there differences in GH ($P<0.01$ and $P<0.1$, respectively). In 1986 (figure 23; table A-6), there was no treatment x period interaction. There was, however, a trend towards higher gain ha^{-1} for LA pastures (482 kg ha^{-1}) when compared to LN (380 kg ha^{-1}) pastures. This trend was most pronounced from mid-August through 2d September, a period when the GH in LN pastures dropped precipitously.

Discussion

Average Daily Gain

Including aeschynomene in limpograss pastures increased seasonal ADGs by 104% in 1985 (0.27 vs 0.55 kg) and by 57% in 1986 (0.54 vs 0.85 kg). In a similar study, Pitman et al. (1985) reported that aeschynomene in bahiagrass pastures also resulted in higher ADG (0.58 vs 0.33 kg $head^{-1}$) when compared to N-fertilized bahiagrass. Pitman (1983) also found that bahiagrass-aeschynomene pastures produced higher ADGs than bahiagrass fertilized at 224 kg N ha^{-1} $year^{-1}$ (0.58 vs 0.48 kg $head^{-1}$ day^{-1}).

Reports in the literature have shown that, although relatively high in digestibility (Quesenberry et al., 1984), CP concentrations in Floralta limpograss were low

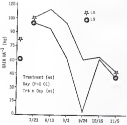

Fig. 23. Gain ha^{-1} of limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986.

enough that ADG of animals grazing this forage may be limited (Gieger, 1986; Sollenberger et al., 1987b, and Quesenberry and Ocumpaugh, 1980). Results of the current study suggest that overseeding aeschynomene in limpograss is an alternative for increasing the quality of animal diets as was suggested by Sollenberger et al. (1987b).

In 1985, ADG in LN pastures for the first 3-week period was less than -0.1 kg head^{-1}, but in 1986 gains were 0.8 kg head^{-1} during the first period. Differences in N fertilization practice would appear to be partially responsible. In 1985, the paddocks where gain was low had received no N from the spring (March) until after the second grazing cycle. The first grazing cycle (light grazing of pastures for 3 weeks) and the first 3 weeks of the second cycle had been completed on grass pastures prior to initiation of grazing on the association (i.e., when the experiment began). In 1986, N was applied after the first grazing cycle resulting in higher CP concentration in early season limpograss and in higher gains.

In both years there was a marked reduction in ADG during August and September in LN pastures. Gain decreased sharply in LA pastures during this period in 1985 but to a lesser degree in 1986. Daily gains reached a minimum of -0.08 and 0.04 kg in LN pastures.

compared to 0.41 and 0.61 kg in LA pastures in 1995 and 1996, respectively. Low ADG during the "summer slump" period on LN pastures is similar to trends reported by Gieger (1995). The difference between LN and LA systems is likely explained by the relatively high CP and IVDOM concentrations in aeschynomene herbage. Approximately 30% of the pregraze herbage mass during the "summer slump" period was legume forage. Sollenberger et al. (1987b) reported that CP of herbage consumed exceeded 7 dag kg^{-1} DM if percentage aeschynomene in herbage accumulated was 15% or higher.

Forage CP and IVDOM Concentrations

As the season progressed, aeschynomene CP concentration (whole plant) dropped from approximately 18 dag kg^{-1} DM to 12 dag kg^{-1} DM. These CP concentrations are in the range of those reported by Mislevy et al. (1981). The decrease in CP was a result of an increased proportion of stem as the grazing season progressed.

Limpograss CP concentration (whole plant) was not different between the two treatments. Average CP, however, was slightly higher than that reported by Sollenberger et al. (1987b) but similar to that found by Euclides (1995). In 1996, there was a trend toward higher CP concentrations for limpograss in LN pastures, especially during the "summer slump" period. Near the end of the grazing season in 1986, limpograss CP concentration was higher in LA than in LN pastures, but the difference is not totally understood. It may be related to better grass utilization throughout the grazing season in LA pastures, hence less accumulation of mature herbage in LA than in LN swards. In addition recycling of legume nitrogen through the animal or free breakdown of legume plants lost from the stand may have contributed (Sollenberger et al., 1987b).

Changes in IVDOM concentration (whole plant) of aeschynomene and limpograss followed patterns similar to CP concentration in both 1985 and 1986. Aeschynomene digestibility decreased as the season progressed, again a result of increased proportion of stem. Limpograss IVDOM concentration (whole plant) was higher for LA pastures than for LN pastures in 1985 because of a greater accumulation of dead material and stems at the base of LN pastures. In 1986, no pronounced trends were apparent, possibly because dead material was not included.

Whole Canopy CP and IVDOM Concentrations

Crude protein of the pregraze canopy (whole plant basis) was calculated for both systems over the 1985 and 1986 grazing seasons. In 1985, limpograss-aeschynomene pastures had a higher CP concentration due to the contribution of the legume to those pastures. In 1986, there was no difference in CP concentration between systems because CP in LN pastures was higher than in 1985. Two factors could have resulted in this response. First, there was better management of N applications on the limpograss pastures in 1986. Secondly, the limpograss fraction in 1985 included dead grass stems and this caused a reduction in CP concentration. In 1986, dead material was separated and discarded before chemical analyses. There was much less dead material in LA pastures due to the spring disking and better utilization of forage during the grazing season, so values in 1985 for CP and digestibility were not affected to as great an extent by dead material as on LN pastures.

There was a trend observed toward higher CP concentrations during the "summer slump" period in LA pastures in 1986. This likely resulted from the contribution of aeschynomene, supporting the suggestion by Hodges et al. (1982) and Sollenberger et al. (1987b) that aeschynomene can provide high quality forage for grazing during the "summer slump" period.

The IVDOM concentration of the pregraze canopy was also studied. Pastures including aeschynomene had higher digestibility in 1985. Digestibility declined over the 1985 grazing season in both pasture systems possibly due to an accumulation of mature stems and dead material at the base of the canopy. Sharpest declines in digestibility in LN pastures occurred during the "summer slump" period in 1985. This may partially explain the drop in animal performance (ADG) during this period, however, in 1986 there was not a similar decline in digestibility. In 1986, better management of the grass swards resulted in no difference in IVDOM concentrations between LA and LN canopies (seasonal means and responses over the season). However, it should be noted that DM intake of legumes is generally greater than that of grasses at similar digestibilities (Thornton and Minson, 1973; Waldo and Jorgenson, 1981). Thus, including aeschynomene in LA pastures may have increased DM intake and animal gains even if forage digestibility was similar.

The CP and IVDOM concentrations calculated for the whole canopy are not likely to be representative of the diet consumed. Since animals select species and plant parts within pasture systems, diet quality is generally higher than that of the whole canopy.

Handplucked Forage Quality

Handplucked samples of limpograss and aeschynomene in LA, and of limpograss in LN pastures were taken to simulate the plant parts selected by the animals. Aeschynomene CP concentration (handplucked) ranged between 20 and 27 dag kg^{-1} DM. These findings are similar to those reported by Gildersleeve (1982) and Sollenberger et al. (1987b). In both years handplucked CP was much higher than that in the pregraze whole canopy indicating selection for leaves and stem tips. Gildersleeve (1982) and Sollenberger et al. (1987b) reported that animals graze aeschynomene leaves and fine stems (less than 4 mm in diameter).

Limpograss CP concentration (handplucked) was higher in LN than in LA pastures. This suggests that the primary benefit of using aeschynomene was providing N to cattle diets and not increasing grass CP. An important fact that should be noticed in the limpograss CP data is that the CP concentration did not decline during the "summer slump" period. These data suggest that limpograss CP concentration may not have been the major factor limiting ADG during the "summer slump" period on these LN pastures, however, changes in digestibility of grass CP over the season should be evaluated. Further studies are needed to determine what additional factors may limit animal gains during this period.

Aeschynomene IVDOM concentration (handplucked) was relatively constant until late September when it began to decline from approximately 76 to 63 dag kg^{-1} OM due to a lower leaf:stem ratio. Similar findings were reported by Gildersleeve (1982) and Sollenberger et al. (1987b).

Limpograss digestibility (handplucked) was not different between LN and LA pastures. Higher limpograss CP concentration in LN pastures did not result in higher limpograss digestibility. It should also be noted that there was no noticeable decline in IVDOM concentration of handplucked and whole plant limpograss in LN and LA pastures that would explain the drop in ADG 's during the "summer slump" period.

Carrying Capacity

A good indication of quantity of herbage accumulated in pasture systems is the determination of carrying capacity using the put and take stocking method (Mott and Lucas, 1952). There were no differences in CC between the two treatments in this study, however, there was a trend toward higher CC in LN pastures suggesting that N-fertilized limpograss pastures produce more grazable forage than associations with legumes (table A-15).

In a related study, Pitman (1983) showed higher CC for bahiagrass-N pastures when compared to bahiagrass-aeschynomene pastures. In the present study, LN pastures produced more herbage especially in July and

August (table A-15) when climatic conditions favored the optimum utilization of N fertilizer. The production of herbage in both LN and LA pastures dropped as the season progressed due to less favorable climatic conditions, consequently, CC was reduced. In the period after 18 Sept. 1985, LA pastures had a higher CC than LN pastures. Aeschynomene plants were taller than the grass, but most of the legume herbage was stem. As discussed earlier, animals select leaves and stems up to 4 mm thick, and they did not graze the aeschynomene stems that were available. The drop in ADG during this period in LA pastures (below the ADG in LN pastures), suggests that these swards were overgrazed and that late in the season stocking decisions on aeschynomene-grass pastures should be based on quantity of grass available. In 1986, stocking rates were decreased late in the season and gains remained high on LA pastures.

Gain per Hectare.

Animal gain ha^{-1} is the most important economic measurement in grazing trials. This response is a product of the ADG and CC (Mott and Lucas, 1952). Limpograss-N pastures tended to have a higher CC than LA pastures, but the higher ADGs obtained in LA pastures resulted in higher gain ha^{-1} for the LA system. It should be noted that the difference between treatments was especially large during the "summer slump" period indicating the potential of the association to supply significant quantities of higher quality herbage during this time.

CHAPTER IV
SUMMARY AND CONCLUSIONS

Studies suggest that low N concentrations in Floralta limpograss (*Hemarthria altissima* [Poir.] Stapf et C. E. Hubb.) may limit animal performance. It was thought that the quality of the grazing animal's diet could be improved by including aeschynomene (*Aeschynomene americana* L.) in limpograss pastures. The objectives of this study were a) to compare average daily gain (ADG), carrying capacity (CC) and gain ha^{-1} of limpograss-N (LN) and limpograss-aeschynomene (LA) pastures, b) to compare crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations of the forage in both systems, and c) to relate animal performance and measures of forage quality.

This study showed higher ADGs in LA pastures than in LN pastures (table 4), thus indicating improved diet quality for animals grazing the association. Handplucked limpograss CP was lower in LA than in LN pastures, since LN pastures were fertilized with N. The CP concentration in limpograss (LN pastures) generally did not drop below 7 dag kg^{-1} dry matter, thus suggesting that factors other than protein deficiency

Table 4. Seasonal animal performance and forage quality data in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985 and 1986.

Item	1985		1986	
	LN	LA	LN	LA
ADG (kg)§	0.27	0.55**	0.54	0.85*
CC¥	17.8	14.6	20.1	18.8
Gain ha^{-1} (kg)	157	206**	383	492
Whole canopy (pregraze)				
CP (dag kg^{-1} DM)¶	6.1	7.8*	8.7	7.7
IVDOM (dag kg^{-1} OM)¶	50.2	58.8*	48.3	48.0
Limpograss (pregraze)				
HCP (dag kg^{-1} OM)ƒ	9.2	7.4*	8.8	7.4*
WPCP (dag kg^{-1} OM)ƒ	4.7	4.5	5.3	5.0
HIVDOM (dag kg^{-1} OM)ф	61.5	64.4	51.3	52.0
WPIVDOM (dag kg^{-1} OM)ф	55.1	58.8***	51.2	50.4

*** Means within the same row and year are different ($P<0.1$).
** Means within the same row and year are different ($P<0.01$).
* Means within the same row and year are different ($P<0.05$).
§ Animal average daily gain.
¥ Pasture carrying capacity expressed as 100 kg liveweights ha^{-1} day^{-1}.
¶ Whole canopy crude protein (CP) and in vitro digestible organic matter (IVDOM) concentration.
ƒ Limpograss handplucked and whole plant CP concentration (HCP and WPCP, respectively).
ф Limpograss handplucked and whole plant IVDOM concentration (HIVDOM and WPIVDOM, respectively).

might have limited animal performance on LN pastures in this study.

The "summer slump" was obvious in this experiment. In both years there was a marked reduction in ADG during August and September in LN and LA pastures. Minimum gains were approximately 0.5 kg head^{-1} day^{-1} higher for LA than for LN pastures during this period. Results of the current study suggest that overseeding aeschynomene in limpograss is one alternative for increasing the quality of animal diets during the summer slump.

Relating the summer ADGs to forage quality characteristics, it was noticed that CP of limpograss (whole plant) in the pregraze canopy did not decline markedly in the summer compared to levels at the beginning or end of the season in both LA and LN pastures in 1985 and 1986 (figure 16 and 17). The IVDOM concentration of limpograss (whole plant) in the pregraze canopy in 1985 decreased as the season progressed as a result of an increased proportion dead material in the forage sampled. In 1986, there was no decline over the season, probably because dead material was excluded from the forage samples. Thus, the forage data do not adequately explain the decline in ADG of animals grazing these pasture systems, and further studies are needed.

In 1985, CP and IVDOM concentration of the pregraze whole canopy (table 4) were significantly higher in LA than in LN pastures due to the contribution of the legume to these pastures. In 1986, however, there were no differences due to the higher limpograss quality which was a result of better early season pasture management and the exclusion of dead forage from samples in 1986.

In 1985, LN pastures were fertilized in March and grazing started in the beginning of May. To control the accumulation of limpograss, paddocks 1, 2, and 3 were grazed together for 1 week followed by paddocks 4 and 5, and lastly paddock 6. By using similar stocking rates during this 3-week period, light, moderate, and optimum grazing pressures were established for paddocks 1 through 3, paddocks 4 and 5, and paddock 6, respectively. The second grazing cycle started in paddock 1, and each subsequent paddock was grazed for 1 week. Fertilizer N was applied after grazing each paddock individually, starting in paddock 1 of the second grazing cycle. As a result, CP of limpograss in LN pastures was quite low until animals reached paddock 1 of cycle 3. The experimental period for this trial did not begin until the fourth week of the second cycle, so it was only during the first 3-week period of grazing that animals were consuming forage that was very low in CP.

By contrast in 1986, grazing of individual paddocks in LN pastures started in the beginning of May. Each paddock was fertilized with N after the initial grazing (1 week). The early season management strategy in 1985 resulted in low forage quality (CP and IVOOM concentrations) in the beginning of the experimental period compared to the similar period in 1986. Further, grazing limpograss pastures early in the grazing season at "optimum" grazing pressure (1986) resulted in less accumulation of mature forage in the subsequent grazing cycles and thus better utilization of the produced forage over the season. Nitrogen fertilization (30 kg ha^{-1}) after each grazing was important in maintaining adequate CP in limpograss during the season. The 1986 pasture management was partially responsible for the gains of 0.5 kg head^{-1} day^{-1} on LN pastures, levels which are near to the maximum obtainable on most tropical and sub-tropical pastures without supplementation.

There were no differences in CC between LA and LN pastures (table 4), however, there was a trend toward higher CC in LN pastures suggesting that N-fertilized limpograss pastures produce more biomass than associations with legumes. Higher biomass production on

LN pastures is supported by dry matter on offer data (table A-15). Gain ha^{-1} was higher for LA than for LN pastures in 1985, and in 1986 the trend was similar. This indicates that although overseeding aeschynomene in limpograss pastures may not increase CC compared to N-fertilized limpograss, the improved ADGs on the legume pastures will result in higher product ha^{-1}, which is the response of greatest economic importance.

The absence of a summer slump in production for animals grazing dwarf elephantgrass (Pennisetum purpureum Schum.) and rhizome peanut (Arachis glabrata Benth.) suggest that the slump is primarily due to changes in the forage, and enviromental effects on the animal are of lesser importance. With this in mind, additional studies with limpograss pastures should be undertaken. Responses to be measured in these trials should include a) changes in digestibility of protein in limpograss over the season, b) changes in neutral detergent fiber, acid detergent fiber, and lignin concentration in limpograss as the season progresses, and c) the effect of time of harvest (including August and September) of limpograss on dry matter intake in confinement. Information is needed on the availability of limpograss plant protein to the animal over the grazing season, and this response might be related to animal performance. Also, measuring DM intake under controlled conditions might allow relationships between intake and forage characteristics to be established.

APPENDIX

Table A-1. Average daily gain of cattle grazing limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985.

Period§	LN	LA
	----- kg head^{-1} day^{-1} ------	
07/17	-0.17±0.09	0.52±0.08**
08/07	0.58±0.09	1.02±0.08**
08/28	0.05±0.09	0.42±0.08**
09/18	0.27±0.09	0.75±0.08**
10/09	0.47±0.10	0.36±0.08
10/30	0.38±0.12	0.20±0.08
Season (126-d)	0.27±0.04	0.55±0.03**

§ Average daily gain reported is an average over the 3-week period preceding the data indicated.
** Means within the same row are different (P<0.01).

Table A-2. Average daily gain of cattle grazing limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986.

Period§	LN	LA
	------kg head^{-1} day^{-1}------	
07/23	0.64±0.14	0.80±0.14
08/13	0.59±0.14	0.84±0.14
09/03	0.39±0.14	0.80±0.14
09/24	0.04±0.14	0.83±0.14
10/15	0.88±0.14	1.10±0.14
11/05	0.71±0.14	0.98±0.14
Season (126-d)	0.54±0.06	0.85±0.06*

§ Average daily gain reported is an average over the 3-week period preceding the date indicated.
* Means within the same row are different (P<0.05).

Table A-3. Carrying capacity (CC) on limpograss-N (LN) and limpograss-aeschynomene (LA) pastures during the grazing season in 1985.

Period §	LN	LA
	100 kg liveweights ha^{-1} day^{-1}	
07/17	21.9±1.2	14.3±1.2***
08/07	26.8±1.2	13.3±1.2*
08/28	24.7±1.2	17.7±1.2***
09/18	18.5±1.2	15.9±1.2
10/09	09.0±1.2	14.3±1.2
10/30	08.6±1.2	12.5±1.2***
Season (126-d)	17.9±0.5	14.8±0.5

§ Carrying capacity reported is an average over the 3-week period preceding the date indicated.

*** Means within the same row are different ($P<0.1$).

* Means within the same row are different ($P<0.05$).

Table A-4. Carrying capacity (CC) on limpograss-N (LN) and limpograss-aeschynomene (LA) pastures during the grazing season in 1986.

Period§	LN	LA
	100-kg liveweights ha^{-1} day^{-1}	
07/23	25.7±1.2	17.9±1.2**
08/13	26.3±1.2	21.5±1.2
09/03	25.9±1.2	21.9±1.2
09/24	18.9±1.2	17.1±1.2
10/15	11.9±1.2	11.0±1.2
11/05	11.0±1.2	11.1±1.2
Season (126-d)	20.1±0.5	16.8±0.5

§ Carrying capacity reported is an average over the 3-week period preceding the date indicated.

** Means within the same row are different (P<0.01).

Table A-5. Animal gain ha^{-1} on limpograss-N (LN) and limpograss-aeschynomene (LA) pastures during the summer in 1995.

Period§	LN	LA
	-------- kg ha^{-1} ----------	
07/17	-25.8±10.9	49.4±10.9**
08/07	105.9±10.9	89.7±10.9
08/28	9.7±10.9	41.2±10.9***
09/18	25.0±10.9	99.7±10.9
10/09	25.2±10.9	32.0±10.9
10/30	19.9±10.9	17.0±10.9
Season (128-d)	26.2±04.5	49.3±04.5**

§ Animal gain reported is an average over the 3-week period preceding the date indicated.
*** Means within the same row are different ($P<0.1$).
** Means within the same row are different ($P<0.01$).

Table A-6. Animal gain ha^{-1} on limpograss-N (LN) and limpograss-aeschynomene (LA) pastures during the summer in 1966.

Period[§]	LN	LA
	---------- kg ha^{-1}	---------
07/23	100.2±17.6	105.5±17.6
06/13	93.6±17.6	115.7±17.6
06/03	63.0±17.6	100.3±17.6
09/24	3.5±17.6	60.2±17.6
16/05	60.7±17.6	63.3±17.6
11/05	41.6±17.6	47.0±17.6
Season (126-d)	60.5±07.2	62.0±07.2

[§] Animal gain reported is an average over the 3-week period preceding the date indicated.

Table A-7. Pre- and postgraze limpograss (whole plant) crude protein concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985.

Date §	Pregraze		Postgraze	
	LN	LA	LN	LA
	----------dag kg^{-1} DM ----------			
07/02,07/11	4.2±0.5	4.9±0.5	2.3±0.3	2.7±0.3
07/16,07/25	6.0±0.5	5.6±0.5	3.6±0.3	4.6±0.3***
07/30,08/06	4.6±0.5	4.6±0.5	3.1±0.3	2.5±0.3
08/13,08/22	3.3±0.5	2.4±0.5	1.9±0.3	1.6±0.3
08/27,09/05	3.9±0.5	4.4±0.5	3.3±0.3	4.4±0.3***
09/10,09/19	5.0±0.5	4.4±0.5	3.7±0.3	3.6±0.3
09/24,10/03	4.1±0.5	3.7±0.5	3.3±0.3	2.5±0.3*
10/08,10/17	4.3±0.5	5.4±0.5	4.1±0.3	4.5±0.3
10/22,10/31	6.7±0.5	5.4±0.5	5.4±0.3	5.0±0.3
Season	4.7±0.2	4.5±0.2	3.4±0.1	3.5±0.1

§ Dates indicated are for pre- and postgraze sampling dates, respectively.

*** Means within the same row and same sample group (pre- or postgraze) are different ($P<0.1$).

* Means within the same row and same sample group (pre- or postgraze) are different ($P<0.05$).

Table A-8. Pre- and postgraze limpograss (whole plant) crude protein concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1988.

Date§	Pregraze LN	Pregraze LA	Postgraze LN	Postgraze LA
	------------	dag kg^{-1}	OM	------------
07/01,07/10	6.8±0.5	5.4±0.5***	5.0±1.8	4.7±1.8
07/15,07/24	4.5±0.5	4.8±0.5	6.0±1.8	5.7±1.8
07/28,08/07	4.7±0.5	3.5±0.5	4.7±1.8	5.0±1.8
08/12,08/21	4.1±0.5	3.5±0.5	6.0±1.8	4.7±1.8
08/28,09/04	6.0±0.5	6.0±0.5	3.7±1.8	4.7±1.8
09/08,09/18	6.2±0.5	5.1±0.5***	4.7±1.8	4.0±1.8
09/23,10/02	5.8±0.5	4.1±0.5	5.3±1.8	5.3±1.8
10/07,10/16	4.8±0.5	6.8±0.5***	4.7±1.8	4.7±1.8
10/21,10/30	4.8±0.5	5.5±0.5	4.0±1.8	3.3±1.8
Season	5.3±0.2	5.0±0.2	4.8±0.6	4.8±0.6

§ Dates indicated are for pre- and postgraze sampling dates, respectively.

*** Means within the same row and same sample group (pre- or postgraze) are different ($P<0.1$).

Table A-5. Pre- and postgraze limpograss (whole plant) in vitro digestible organic matter concentration (IVDOM) in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985.

Date§	Pregraze LN	Pregraze LA	Postgraze LN	Postgraze LA
	---------------dag kg^{-1} OM	---------------	---------------	---------------
07/02,07/11	58.1±4.1	65.5±4.1**	55.5±1.5	61.9±1.5*
07/16,07/25	61.6±4.1	64.6±4.1	57.7±1.5	59.9±1.5
07/30,08/08	58.1±4.1	61.7±4.1*	49.2±1.5	58.1±1.5**
08/13,08/22	55.8±4.1	59.0±4.1	50.4±1.5	54.7±1.5*
08/27,09/05	57.4±4.1	58.9±4.1*	48.7±1.5	54.5±1.5*
09/10,09/19	49.0±4.1	55.9±4.1	48.1±4.1	54.9±1.5**
09/24,10/03	50.3±4.1	53.1±4.1	48.2±1.5	52.5±1.5
10/08,10/17	52.4±4.1	57.2±4.1	45.5±1.5	54.1±1.5*
10/22,10/31	53.4±4.1	54.1±4.1	47.5±1.5	50.3±1.5
Season	55.1±1.4	58.6±1.4***	49.9±0.5	55.8±0.5**

§ Dates are pre- and postgraze sampling dates, respectively.

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).

** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).

* Means within the same row and same sample group (pre- postgraze) are different (P<0.05).

Table A-10. Pre- and postgraze limpograss (whole plant) in vitro digestible organic matter concentration (IVDOM) in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1966.

Date§	Pregraze LN	Pregraze LA	Postgraze LN	Postgraze LA
	----------------	dag kg^{-1} OM	----------------	
07/01,07/10	54.8±1.8	52.5±1.6	50.0±3.8	51.3±3.8
07/15,07/24	51.8±1.6	52.4±1.8	47.7±3.8	50.7±3.8**
07/29,08/07	53.3±1.8	49.7±1.8	49.3±3.6	49.0±3.8
08/12,08/21	51.5±1.8	50.7±1.8	47.3±3.8	47.7±3.8
08/28,09/04	50.8±1.8	51.0±1.8	49.0±3.8	49.0±3.8
09/09,09/18	51.0±1.8	48.8±1.8*	45.7±3.8	48.3±3.6***
09/23,10/02	51.1±1.8	48.3±1.8	45.0±3.6	48.0±3.8
10/07,10/18	49.3±1.8	51.4±1.8	44.6±3.8	47.7±3.8
10/21,10/30	47.5±1.8	50.9±1.6	47.7±3.8	48.7±3.8
Season	51.2±0.8	50.4±0.8	47.3±1.2	48.7±1.2

§ Dates indicated are pre- and postgraze sampling dates, respectively.

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).

** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).

* Means within the same row and same sample group (pre- postgraze) are different (P<0.05).

Table A-11. Handplucked limpograss CP and IVDOM concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1665.

	IVDOM		CP	
Date	LN	LA	LN	LA
	-----dag kg^{-1} OM---		---dag kg^{-1} OM---	
07/02	61.2±2.6	63.6±2.6	6.2±0.9	7.0±0.6
07/16	61.6±2.6	64.5±2.6	12.6±0.6	6.1±0.6*
07/30	56.0±2.6	56.2±2.6	6.7±0.6	6.6±0.6***
06/13	60.6±2.6	61.6±2.6	6.7±0.6	7.2±0.6*
06/27	56.1±2.6	64.0±2.6*	6.6±0.6	7.6±0.6
06/10	63.3±2.6	64.1±2.6	6.6±0.6	7.6±0.9
06/24	62.5±2.6	65.5±2.6	6.0±0.9	7.0±0.6
10/06	63.6±2.6	65.6±2.6	6.6±0.6	7.6±0.6
10/22	63.1±2.6	73.3±2.6	10.7±0.6	7.6±0.6***
Season	61.5±0.6	64.4±0.6	6.2+0.3	7.4±0.3*

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).

** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).

* Means within the same row and same sample group (pre- postgraze) are different (P<0.05).

Table A-12. Handplucked limpograss CP and IVOOM concentration in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1986.

	IVOOM		CP	
Date	LN	LA	LN	LA
	----dag kg^{-1}	OM----	---dag kg^{-1}	OM---
07/01	54.6±1.6	55.7±1.6	12.0±0.7	9.1±0.6
07/15	53.4±1.6	54.5±1.6	9.0±0.7	7.4±0.6*
07/29	50.0±1.6	46.4±1.6***	6.3±0.7	5.6±0.6 *
08/12	52.0±1.6	48.6±1.6	9.4±0.7	7.4±0.8***
08/26	51.8±1.6	46.5±1.6	10.4±0.7	7.6±0.6**
09/09	46.7±1.6	53.5±1.6***	9.1±0.7	7.3±0.8
09/23	49.4±1.6	55.1±1.6*	7.6±0.7	6.5±0.6
10/07	46.2±1.6	50.3±1.6	6.6±0.7	7.6±0.6
10/21	52.6±1.6	54.6±1.6	6.1±0.7	8.0±0.6
Season	51.3±0.5	52.0±.5	6.6±0.2	7.4±0.2*

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).
** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).
* Means within the same row and same sample group (pre- postgraze) are different (P<0.05).

Table A-13. Crude protein and IVDOM concentrations in the pregraze canopy in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1995.

Date	Crude protein		IVDOM	
	LA	LN	LA	LN
	-dag kg^{-1}	DM-	-dag kg^{-1}	DM--
07/02	8.6	4.9	64.1	49.7 **
07/16	6.8	7.5	63.2	56.7
07/30	7.5	5.8 ***	59.4	54.7 **
08/13	6.4	4.7 *	58.5	50.9 **
08/27	9.0	5.7 **	58.9	54.1 *
10/10	8.0	6.9	54.8	44.8 *
10/24	7.7	5.7	52.5	44.2 *
10/08	9.6	5.9 *	54.1	48.2
10/22	7.6	7.4	45.9	48.4
Season	7.9	6.1 *	56.8	50.2 *

*** Means within the same row and same sample group (pre- or postgraze) are different ($P<0.1$).
** Means within the same row and same sample group (pre- or postgraze) are different ($P<0.01$).
* Means within the same row and same sample group (pre- postgraze) are different ($P<0.05$).

Table A-14. Crude protein and IVDOM concentrations in the prегraze canopy in limpograss-N (LN) and limpograss-aeschynomene pastures in 1988.

	IVDOM			Crude protein	
Date	LN	LA		LN	LA
	--dag kg^{-1} OM--			--dag kg^{-1} OM--	
07/01	47.11	49.17		7.83	8.35
07/15	47.38	50.00		5.30	8.36
07/29	47.87	48.35		8.00	5.59
08/12	45.87	49.25		5.81	5.38
08/26	48.89	49.48		7.23	8.83
09/09	48.37	44.04	***	7.81	8.19
09/23	45.34	47.38		7.28	7.56
10/07	45.87	48.81		8.03	12.13 **
10/21	44.35	48.27		8.95	8.25
Season	48.25	48.27		8.71	7.74

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).

** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).

Table A-15. Pregraze herbage mass in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985 and 1986.

	Pregraze herbage mass (kg DM ha^{-1})			
	1985		1986	
Date§	LN	LA	LN	LA
07/02, 07/01	5937	3957**	4242	3529
07/16, 07/15	8841	3566**	6206	3672**
07/30, 07/29	7750	4793	4319	4243
08/13, 08/12	7506	5550	6058	4447
08/27, 08/26	4936	3870	4347	5295
09/10, 09/09	5599	5362	3395	2932
09/24, 09/23	4565	4511	3029	2494
10/08, 10/07	3566	5008	2129	3782**
10/22, 10/21	4594	5101	2059	1678
Season	5912	4635***	3976	3571

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).

** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).

§ Dates are for 1985 and 1986 sampling dates, respectively.

Table A-18. Postgraze herbage mass in limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985 and 1986.

	Postgraze herbage mass (kg OM ha^{-1})			
	1985		1986	
Dates§	LN	LA	LN	LA
07/11, 07/10	3081	2831	2300	1980
07/25, 07/24	8327	2813**	3442	2306
08/08, 08/07	8521	3477***	2843	1852***
08/22, 08/21	4874	2401*	3384	1444***
09/05, 09/04	4185	2487	2843	3048
09/19, 09/18	4883	4080	3083	2048***
10/03, 10/02	3358	2830	2262	1813
10/17, 10/16	3267	3843	1540	1831
10/31, 10/30	3883	3538	1277	811
Season	4444	3187***	2584	1883**

§ Dates are for 1985 and 1986 sampling dates, respectively.

*** Means within the same row and same sample group (pre- or postgraze) are different (P<0.1).

** Means within the same row and same sample group (pre- or postgraze) are different (P<0.01).

* Means within the same row and same sample group (pre- or postgraze) are different (P<0.05).

Table A-17. Aeschynomene regression equations relating canopy characteristics (y) to day of grazing season (x) in 1985 and 1986.

		R	P<	S
Legume % pregraze canopy				
1985	$7.91+0.885X-0.00407X^2$	58.8	0.01	7.2
1986	$1.78+0.307X$	80.7	0.01	8.9
Handplucked IVDOM				
1985	$78.2-0.0581X+0.00329X^2-0.000033X^3$	86.5	0.01	1.7
1986	$79.4-0.444X+0.00885X^2-0.000054X^3$	72.5	0.01	2.4
Pregraze IVDOM (whole plant)				
1985	$69.1-0.191X$	88.0	0.01	5.0
1986	$62.7-0.0878X$	43.1	0.01	3.8
Postgraze IVDOM (whole plant)				
1985	$62.2-0.37X+0.00134X^2$	89.7	0.01	3.2
1986	$80.2-0.555X+0.00358X^2$	54.7	0.01	5.0
Handplucked CP				
1985	$21.8+0.199X-0.00189X^2$	38.4	0.01	2.7
1986	$23.2+0.132X-0.00125X^2$	37.3	0.01	2.1
Pregraze CP (whole plant)				
1985	$18.2-0.0554X$	53.7	0.01	1.9
1986	$17.4+0.0427X-0.000534X^2$	20.3	0.10	1.9
Postgraze CP (whole plant)				
1985	$13.8-0.0531X$	58.8	0.01	1.7
1986	$18.2-0.182X+0.00118X^2$	44.7	0.01	1.8

Table A-18. Animal breeds of testers used on limpograss-N (LN) and limpograss-aeschynomene (LA) pastures in 1985 and 1986.

	4 testers pasture
1985	1* (1/2 Hereford*1/4 Brahman*1/8 Brown Swiss*1/8 Angus)
	2* (1/2 Hereford*1/4 Romana Red*1/8 Angus*1/8 Brown Swiss)
	1* (1/2 Hereford*1/4 Brahman*1/4 Angus)
1986	1* (1/2 Hereford*1/4 Brahman*1/8 Angus*1/8 Brown Swiss)
	2* (1/2 Brahman*1/4 Brown Swiss*1/4 Angus)
	1* (1/2 Hereford*1/4 Romana Red*1/8 Angus*1/8 Brown Swiss)

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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